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MATHEMATICS COURSE REQUIREMENTS AND PERFORMANCE LEVELS IN THE NAVY'S BASIC ELECTRICITY AND ELECTRONICS SCHOOLS

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Instructors in the Navy's Basic Electricity and Electronics (BE/E) schools were presented with a list of 70 mathematical skills and asked to indicate (1) how important they were to successful BE/E school performance and (2) whether they were prerequisite, reviewed, or taught in the schools. Also, they were asked to state the number and type of performance aids used in the course and during the exam. Responses showed that, of the 70 skills surveyed, 21 were rated as affecting performance. Based on survey results, a mathematics test was developed to assess BE/E student performance on skills rated as

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affecting performance, and administered to groups of students entering and graduating from BE/E school. Results showed that student performance was marginal in most topic areas considered critical to course performance by instructors. This suggests that either the instructors overrated the importance of these skills or the criteria for successful BE/E completion are too low.

FOREWORD

This research and development was conducted under exploratory development task area ZF63.522.011 (Assessment and Enhancement of Prerequisite Skills), work unit 522.011.03.02 (Enhancement of Computational Capabilities), and was sponsored by the Chief of Naval Operations (OP-01). The objectives of this work unit are to identify mathematics skill deficiencies among Navy electronics personnel, to determine the causes of such deficiencies, and to develop instruction strategies to improve the efficiency and job relevance of Navy electronics training.

This report is the third in a series designed to identify mathematical requirements relevant to electronics training. The first (NPRDC TR 81-4) described the mathematics skills required for successful performance in Navy electronics "A" schools; and the second (NPRDC TR 82-2), the mathematics skills of entering and graduating "A" school students. The purpose of the present effort was to identify the mathematics skills required to perform successfully in the Navy's Basic Electricity and Electronics (BE/E) schools. Results are intended for use by the Chief of Naval Education and Training and the Chief of Naval Technical Training.

Appreciation is expressed to the BE/E school instructors who participated in this study.

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SUMMARY

Problem and Background

The sophistication of military equipment is increasing while training budgets are decreasing. Thus, to assure cost-effective training, skills and knowledge essential to successful job performance in the fleet and subordinate skills that enable the trainee to master the essential skills must be identified. Conversely, skills and knowledge not required for successful performance must be identified and removed from the entrance standards and course objectives. To address this problem, the Center is conducting a project designed to identify mathematical requirements relevant to electronics training. Previous reports issued concerning this project identified the skills required to perform successfully in Navy electronics "A" schools and compared the mathematics skills of entering and graduating "A" school students.

Objective

The objectives of this study were to identify those mathematics skills required for success in the Navy's Basic Electricity and Electronics (BE/E) school, and, based on results obtained, to assess BE/E school student performance levels in these skills.

Approach

BE/E school instructors were asked to assess the importance of 70 mathematics skills for successful electronics course performance, to indicate whether the surveyed skills were prerequisite, reviewed, or taught by the BE/E school, to state the number and type of performance aids used in the school, and to indicate how much time they spent reviewing and teaching all mathematics topics surveyed. Based on results obtained, a mathematical test was developed to assess BE/E school student performance on skills rated by instructors as affecting performance, and administered to groups of students entering and graduating from BE/E school. Mean scores obtained by entering students without calculators and graduating students without calculators on the total test and on topic areas were compared. Also, the mean scores obtained by graduating students with calculators were compared with those obtained by graduating students without calculators.

Findings

1. Instructors rated 21 mathematics skills as affecting performance in BE/E school. Six of these skills were rated as prerequisite to the BE/E course, 2 are reviewed, and 13 are taught. The total time spent reviewing these skills ranged from 0 to 1 hour; and the total time spent teaching, from 0 to 10 hours.

2. Performance aids are permitted during the BE/E course and examinations. The nonprogrammable calculator is the most universally used computation aid.

3. Across all BE/E schools, mean percent correct on mathematics items essential for successful course performance was 55 for entering students, 68 for graduating students without calculators, and 73 for graduating students with calculators.

4. Significant differences were found between mathematics scores of entering and graduating students who did not use calculators in both total test scores and individual topic scores.

5. Significant differences were found between graduating students with calculators and those without calculators in the total test scores and in three topic areas--arithmetic operations, units and conversions, and scientific notation.

Conclusions

1. Student performance was marginal in most topic areas considered critical to course performance by instructors, suggesting that the importance of these skills was overrated by instructors or that the criteria for successful completion are too low.

2. Students are not well prepared for the Arithmetic Operations and the Fractions topic areas, both of which are prerequisites for the BE/E course, indicating that training in these subjects in their preservice schools was inadequate.

Recommendations

Further studies should be conducted to validate the claims of BE/E instructors that the mathematics standards now set are indeed critical to an understanding of electronics and to the solution of electronics problems. Results should be used to determine what mathematic topics are essential to performance, what topics are enabling for another skill critical to performance, and what topics are not critical and should be dropped from the curriculum.

These studies are currently being conducted by NAVPERSRANDCEN.

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INTRODUCTION

Problem

The sophistication of military equipment is increasing while training budgets are decreasing. Thus, to assure cost effective training, skills and knowledge essential to successful job performance in the fleet and subordinate skills necessary to master essential skills must be identified. Conversely, skills not required for successful performance must be identified and removed from the entrance standards and course objectives.

Navy recruits are assigned to ratings and corresponding Class "A" schools based on scores obtained on the Armed Services Vocational Aptitude Battery (ASVAB). Over 23,000 of the approximately 60,000 recruits who enter Navy Class "A" schools every year are trained in electronics maintenance. Before these recruits enter "A" school, however, they must successfully undergo training on the fundamentals of electronic theory at one of the Basic Electricity and Electronics (BE/E) preparatory schools. Since the BE/E course and all follow-on courses use mathematics to express relations in electronic systems, students are given a diagnostic mathematics test prior to entering BE/E. Those who have deficiencies in mathematics are referred to remedial mathematics units, but are not tested on these units.

Background

Although the ASVAB requirements for the electronics schools are more stringent than for most areas of Navy technical training, many students are not prepared to begin the BE/E school curriculum. A deficiency in mathematics is a primary contributor to unsatisfactory performance in electronics.

To address this problem, the Navy Personnel Research and Development Center is conducting R&D designed to identify mathematical requirements relevant to electronics training. The purpose of the first task conducted under this R&D was to identify the mathematical skills necessary for successful performance in the Navy's electronics "A" schools.[1] After a review of several electronics mathematics textbooks, including the principal one used by Navy electronics schools, Basic Mathematics for Electronics,[2] 70 candidate skills were identified and grouped into 14 topic areas. Next, a survey form was developed that included two example problems for each of the 70 skills identified. These problems represented the range of difficulties found in the review of electronics mathematics materials.

This survey was administered to instructors in 14 electronics "A" schools (12 basic and 2 advanced). For each skill, respondents were asked to indicate the level of importance of the skill to the course. Responses were to be made on a 6-point scale with 5 indicating "Indispensable" and 0, "Not required." For skills rated as affecting

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[1]Sachar, J., & Baker, M. S. Mathematical requirements in Navy class "A" electronics schools. (Tech. Rep. No. 81-4). San Diego: Navy Personnel Research and Development Center, January 1981. (AD-A093 946)

[2]Cooke, N. M., & Adams, H. E. R. Basic mathematics for electronics. New York: McGraw Hill, 1970.

performance (i.e., above 1), respondents were asked to indicate the level of instruction provided on a 3-point scale, with P indicating "Prerequisite" (must possess skill on entrance to course), R indicating "Reviewed" (some level of skill is assumed, but skill is reviewed in course), and T indicating "Taught" (no previous knowledge assumed, taught explicitly as a skill for the course). For curriculum design and development, it is necessary to know if required skills are taught in the training courses or are learned by the student before he entered the Navy. Finally, for skills indicated as being reviewed or taught, respondents were asked to state the amount of time spent reviewing or teaching the skills and whether any items relevant to the skills appeared on course tests.

Based on survey results, Berger, Cremer, Marr, and Berger[3] developed tests to assess the performance of entering and graduating "A" school students on those skills rated as affecting performance. These tests were administered to entering and graduating students of "A" schools included in the previous study.

Purpose

The purposes of this effort were to identify those mathematics skills that are required to perform successfully at the Navy's BE/E schools, and, based on results, to assess BE/E school student performance levels in these required skills. The validity of these requirements was not addressed.

APPROACH

Identification of Skills Necessary for Successful BE/E Performance

The survey developed by Sachar and Baker (1981) was administered simultaneously to 12 senior BE/E instructors, three from each of the BE/E school locations at Great Lakes, Orlando, San Diego, and Memphis. These instructors were attending a BE/E school standardization conference at the Service School Command, Naval Training Center, San Diego, on 13 March 1980. It was stressed that responses should apply to the entire course as presently taught, and not to the instructor's opinion of how the course should be taught.

After the instructors completed the survey, the experimenter discussed the entire survey with the group, one skill at a time. Skills that elicited different responses were discussed. If consensus could not be reached on these skills, individual responses were recorded. After the discussion session, the instructors listed the kind of mathematics performance aids (e.g., calculators, formula sheets, slide rules), if any, students use during the course and/or during the examination. The entire session took approximately 50 minutes.

BE/E Students' Performance on Required Mathematical Skills

Test Development

Survey results provided the basis for determining the type and number of items to be selected or constructed for a test covering skills identified as necessary for success in BE/E school. The skill acquisition levels (prerequisite, reviewed, or taught) provided the basis for emphasizing relative difficulty or relative ease of items within a skill.

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[3]Berger, R. M., Marr, D., Cremer, R. H., & Berger, F. R. Mathematical skill levels in Navy class "A" electronics schools (NPRDC Tech. Rep. 82-2). San Diego: Navy Personnel Research and Development Center, October 1981.

For the most part, items were selected from those developed by Berger et al. and included in tests administered to Navy class "A" electronics students. In cases where there were not enough items, new ones were constructed, using the Cooke and Adams textbook as the principal reference. To conform with BE/E requirements for computerized scoring, all items were multiple-choice (four choices).

The primary considerations in constructing the test were ensuring that (1) the test reflected instructor ratings of mathematics skills, (2) the number of items selected were appropriate for a 2-hour test, and (3) items represented reliable measures of mathematics skills. The final test, which consisted of 100 items, was printed on two 50-item forms to accommodate computerized answer sheets. Table 1 shows the number of items included under each required skill area.

Table 1

Number of Items Selected/Constructed by Topic and Skill Areas

Topic	Skill No.	No. of Items	
Arithmetic Operations with Numbers	1	10	
	2	5	
	4	4	
			19
Fractions	6	5	
	7	4	
	9	5	
	10	4	
			18
Units and Conversions	11	4	
	12	4	
	13	5	
	16	5	
			18
Scientific Notation	18	4	
	19	5	
	20	3	
	21	5	
			17
Equations	27	5	
	28	5	
	29	4	
			14
Geometry and Trigonometry	45	5	
	46	4	
	47	5	
Total	21		14
			100

Pretest of Mathematics Test

The mathematics examination was pretested at the Technical Training Preparatory School (TTPS), Service School Command, San Diego, in March 1980. Subjects were students in WAITS status for BE/E at TTPS. Testing was conducted in four 2-hour sessions, two morning and two afternoon, with approximately 25 students in each session. Students were given 1 hour to complete each test form. Trigonometry tables were provided, but calculators were not permitted.

Results showed that test scores ranged from 24 percent to 97 percent, with a mean of 61 and a standard deviation of 18.43. Item difficulty ranged from 22 to 89, with most items falling in the 40 to 70 difficulty range. Item discrimination ranged from -.30 to .89, with the majority falling between .30 and .60.

Kuder Richardson 20 (KR-20) reliability coefficients were computed for the entire test and each test topic. The test-total reliability was .949, and test-topic reliabilities ranged from .61 to .83 (Table 2). Acceptable reliability levels are difficult to set, especially for topics with a small number of items. A low reliability reduces the validity coefficient of the test or test part, and there are no strict criteria for the lower limits of reliability coefficients. It seems reasonable, however, to require a reliability estimate of at least .80. Therefore, results indicate that the total mathematics test has strong internal consistency. On the other hand, the majority of topic areas had only approximately 15 items, so it is not surprising that reliability coefficients by topic were somewhat lower than those for the total test. Although an increased number of items would probably make the topic tests more acceptable as a separate measure, reliability coefficients were accepted as adequate for this research.

Table 2

Pretest Topic Reliabilities (KR-20)

Topic	Number of Items	Reliability
Arithmetic Operations with Numbers	19	.81
Fractions	18	.80
Units and Conversions	18	.79
Scientific Notation	17	.83
Equations	14	.78
Geometry and Trigonometry	14	.61

Within each topic area, items were ranked on the basis of their discrimination and difficulty levels. An item was considered to be in the acceptable range of difficulty if between 20 and 90 percent of the students answered the item correctly. Although the minimum acceptable level of discrimination was set at .30, the vast majority of items had a discrimination level above .40. Eleven items did not meet the minimum level of acceptable discrimination. These items were replaced with new ones and the final form of the test was prepared.

Test Administration

The final test was administered separately to entering and graduating students at the four BE/E schools during the last week of May 1980.[4] Students in the entering group were all in WAITS status. Those in the graduating group had either completed Module 22 of the course (if their rating required completion of all 25 BE/E modules) or Module 11 (if their rating required completion of only the first 11 to 14 modules). All ratings attending BE/E school at the time of test administration were included in the sample. The numbers of students tested at the four BE/E locations are shown in Table 3.

Table 3

Number of Subjects by Location (BE/E Testing)

Location	Entering	Graduating
Memphis	95	109
Orlando	67	78
Great Lakes	71	104
San Diego	135	86
Unknown	5[a]	0
Total	373	377

[a]Five subjects did not record their location.

Testing followed the pilot-test procedure. However, although calculators were not permitted during the pretest because few entering students had them, they were allowed during the graduate-group test because approximately half the students had them. The test was given in one session and took approximately 2 hours.

Mean scores obtained by entering students without calculators and graduating students without calculators on the total test and on topic areas were compared. Also, the mean scores obtained by graduating students with calculators were compared with those obtained by graduating students without calculators.

[4]A copy of this test is available upon request from NAVPERSRANDCEN (Code 15).

RESULTS

Identification of Skills Necessary for Successful BE/E Performance

Table 4 lists the 70 mathematics skills surveyed by the BE/E instructors and indicates the importance assigned to each. As shown, 21 of the 70 skills were rated as required or affecting performance (i.e., above 1). This result is not surprising, since the BE/E course consists of self-paced, mastery-learning instructions. Students do not proceed in the course until they evidence mastery, and they cannot pass the course until they can perform all mathematics required by any given test item. In some cases, course test items are strictly mathematics. Most often, however, the mathematics required is necessary as an enabling skill to solve electronics problems that are predominantly theory and involve mathematics as a subcomponent.

Table 4 shows that the BE/E school required the student to have knowledge in 6 skills prior to entering the course (P), provided review in 2 skills (R), and provided instruction, as part of the curriculum, in 13 (T). Skills indicated as prerequisites to the course are assumed by BE/E instructors to have been learned by students before they entered the Navy.

Instructors indicated they spent from 0 to 1 hour reviewing mathematics topics that instructors rated as affecting BE/E course performance, and from 0 to 10 hours teaching these mathematics topics. The little time spent reviewing and teaching makes it apparent that students entering BE/E are expected to have some sophistication in mathematics.

Finally, the instructors noted that performance aids that speed mathematics operations and increase accuracy are allowed in the BE/E course and examinations. Because of its low cost, the simple calculator is used most often for arithmetic calculations. Few mathematical operations are performed without the use of this aid. Another aid to solving problems, formula sheets, are provided at the outset of BE/E training and are available to students throughout the course and during examinations. Formula sheets provide samples of all formulas involved in the solution of electrical or electronics problems.

BE/E Students' Performance on Required Mathematical Skills

The results of the mathematics test developed based on the above findings were analyzed to provide split-half reliability coefficients with Spearman Brown correction applied. Table 5 presents these reliability coefficients by group and location, and by group total across locations.

Since the same mathematics test was given at all schools to both the entering and graduating students, it was possible to compare the two groups and the four locations directly. As shown in Table 6, the mean percent correct on mathematics items rated by instructors as being essential for successful course performance ranged from 50 to 61 percent for entering students and 69 to 76 percent for graduating students. Scores for the entire entering group, across all locations, ranged from 21 to 99 with a mean of 54.9 and a standard deviation of 18.7. Scores for the entire graduating group, across all locations, ranged from 22 to 100 with a mean of 71.7 and a standard deviation of 15.5. (Data from the two groups of graduating students--those completing all 25 BE/E modules and those completing only the first 11 or 14 modules--were combined because there are no new BE/E mathematics requirements after Module 11.)

Table 4

Importance (I) and Skill Acquisition Level (L) Ratings Assigned to Mathematical Skills, and Hours (H) Spent Reviewing and Teaching Topics

Topic Area/Component Skills	I[a,b]	L[c]	Hours
Arithmetic Operations with Numbers (4):			
1. Addition, subtraction, multiplication, and division of numbers	5	P	
2. Squares and square roots of positive numbers	3	P	
3. Powers and roots of positive numbers greater than squares and square roots	0	-	
4. Percentages of numbers	5	R	
	(3)		1R
Estimation (1):			
5. Estimation of answers to arithmetic computation	0	-	
	(0)		-
Fractions (5):			
6. Addition and subtraction of fractions	5	P	
7. Multiplication and division of fractions	5	P	
8. Powers and roots of fractions	0	-	
9. Reduction of numeral fractions to lowest terms	5	P	
10. Simplification of complex fractions	5	R	
	(4)		1R
Units and Conversions (7):			
11. Addition and subtraction of like units	5	T	
12. Multiplication and division of like units	5	T	
13. Multiplication and division of unlike units	5	T	
14. Squares and square roots of units	-	-	
15. Unit conversion between nonmetric and metric systems	0	-	
16. Unit conversion within a metric system	5	T	
17. Unit conversion within a nonmetric system	0	-	
	(4)		7T
Scientific Notation (4):			
18. Representation of numbers in scientific notation	5	T	
19. Addition and subtraction of numbers in scientific notation	5	T	
20. Multiplication and division of numbers in scientific notation	5	T	
21. Powers and roots of numbers in scientific notation	5	T	
	(4)		1T
Decibels (1):			
22. Decibels	0	-	
	(0)		-

[a]Importance (I) ratings are based on responses made on a 6-point scale, where 0 = Not required, 1 = Dispensable, 2 = Somewhat useful, 3 = Generally useful, 4 = Very important, and 5 = Indispensable.

[b]Numbers in parentheses are the total number of skills within a topic area that affect performance (i.e., they were rated above "1" in importance).

[c]Skill acquisition level (L) ratings are based on responses made on a 3-point scale, where P = Prerequisite, R = Reviewed, and T = Taught.

Table 4 (Continued)

Topic Area/Component Skills	I[a,b]	L[c]	Hours
Logarithms (4):			
23. Logs and antilogs found from log tables	0	-	
24. Arithmetic computation using logs	0	-	
25. Solution of logarithmic and exponential equations	0	-	
26. Logs of numbers to bases other than 10, using base 10 log tables	0	-	
	(0)		0
Equations (6):			
27. Substitution of known values into a given formula	5	T	
28. Transpositions of algebraic expressions	5	T	
29. Application of transpositions on equations with more than one variable	5	T	
30. Solutions of quadratic equations	0	-	
31. Solutions of second-order simultaneous equations	0	-	
32. Solutions of third-order simultaneous equations	0	-	
	(3)		10T
Algebraic Expressions (9):			
33. Addition and subtraction of algebraic expressions	0	-	
34. Multiplication and division of simple algebraic expressions	0	-	
35. Multiplication of algebraic expressions up to binomials	0	-	
36. Multiplication of algebraic expressions larger than binomials	0	-	
37. Division of algebraic expressions	0	-	
38. Powers and roots of simple algebraic expressions	0	-	
39. Powers and roots of polynomials	0	-	
40. Addition and subtraction of fractional algebraic expressions	0	-	
41. Factoring algebraic expressions	0	-	
	(0)		-
Determinants (2):			
42. Evaluation of determinants	0	-	
43. Solutions of simultaneous equations during determinants	0	-	
	(0)		-

[a]Importance (I) ratings are based on responses made on a 6-point scale, where 0 = Not required, 1 = Dispensable, 2 = Somewhat useful, 3 = Generally useful, 4 = Very important, and 5 = Indispensable.

[b]Numbers in parentheses are the total number of skills within a topic area that affect performance (i.e., they were rated above "1" in importance).

[c]Skill acquisition level (L) ratings are based on responses made on a 3-point scale, where P = Prerequisite, R = Reviewed, and T = Taught.

Table 4 (Continued)

Topic Area/Component Skills	I[a,b]	L[c]	Hours
Geometry and Trigonometry (8):			
44. Conversion of radian and degree measures of angles	0	-	
45. Pythagorean theorem	5	P	
46. Use of trigonometric tables to find specified function of a given angle or the angle of a given function	5	T	
47. Solutions to right triangles	5	T	
48. Calculations of the area of a given triangle	0	-	
49. Solutions for unknown parts of a nonright triangle using laws of sines or consines	0	-	
50. Solutions of amplitude, frequency, phase angle, period, and angular velocity of a given periodic function	0	-	
51. Amplification of sum and difference identities	0	-	
	(3)		6T
Phasors (7):			
52. Conversion of polar and rectangular coordinates	0	-	
53. Powers and roots of signed numbers	0	-	
54. Addition and subtraction of phasors in rectangular form	0	-	
55. Addition and subtraction of polar phasors	0	-	
56. Multiplication and division of phasors in rectangular form	0	-	
57. Multiplication and division of polar phasors	0	-	
58. Powers and roots of polar phasors	0	-	
	(0)		-
Number Bases (4):			
59. Conversion of numbers to different number systems	0	-	
60. Addition and subtraction in number systems from #59	0	-	
61. Multiplication and division in number systems from #59	0	-	
62. Complements of binary numbers	0	-	
	(0)		-
Boolean Algebra (8):			
63. Conversion of Boolean expressions to truth tables	0	-	
64. Conversion of logic diagrams to truth tables	0	-	
65. Conversions of Boolean expressions to logic diagrams	0	-	
66. Simplification of Boolean expressions	0	-	
67. Conversion of logic diagrams to Boolean expressions	0	-	
68. Simplification of Boolean expressions involving minterms (Veitch diagrams)	0	-	
69. Coversion of truth tables to Boolean expressions	0	-	
70. Conversion of truth tables to logic diagrams	0	-	
	(0)		-
Total	(21)		2R/24T

[a]Importance (I) ratings are based on responses made on a 6-point scale, where 0 = Not required, 1 = Dispensable, 2 = Somewhat useful, 3 = Generally useful, 4 = Very important, and 5 = Indispensable.

[b]Numbers in parentheses are the total number of skills within a topic area that affect performance (i.e., they were rated above "1" in importance).

[c]Skill acquisition level (L) ratings are based on responses made on a 3-point scale, where P = Prerequisite, R = Reviewed, and T = Taught.

Table 5

Split-Half Reliability Coefficients with Spearman-Brown Correction Applied by Group and Location

Location	Entering Group	Graduating Group
Memphis	.86	.84
Orlando	.86	.82
Great Lakes	.86	.87
San Diego	.88	.86
Total (All Locations)	.88	.85

Table 6

Mean Percent Correct by Location on Total Test

Location	Entering %	Graduating %
Memphis	53	69
Orlando	50	71
Great Lakes	51	71
San Diego	61	76
Total (All Locations)	55	72

Table 7 presents the mean percent correct by topic for the entire entering group and for subgroups of the graduating group--those with and those without calculators. The t-test for independent groups was applied to the total test and topic mean score differences between (1) entering students and graduating students without calculators, and (2) graduating students with calculators and those without calculators. Results showed that the differences between mean scores of entering and graduating students without calculators were significant for the total test ($t = 8.86$, $p < .001$) and for all of the topic areas (Arithmetic Operations, $t = 5.98$, $p < .001$; Fractions, $t = 3.74$, $p < .001$; Units and Conversions, $t = 12.47$, $p < .001$; Scientific Notation, $t = 9.26$, $p < .001$; Equations, $t = 5.11$, $p < .001$; Geometry and Trigonometry, $t = 5.93$, $p < .001$.) Differences between the mean scores of graduating students with calculators and those without calculators were statistically significant for the total test ($t = 3.27$, $p < .001$), and for three topic areas (Arithmetic Operations, $t = 6.01$, $p < .001$; Unit and Conversions, $t = 3.22$, $p < .001$, and Scientific Notation, $t = 4.56$, $p < .001$).

Table 7

Mean Percent Correct for Sample Groups by Topic

Topic	Entering Students Without Calculators (N = 373)	Graduating Students Without Calculators (N = 194)	Graduating Students With Calculators (N = 183)
Arithmetic Operations (19 items)	73	82	90
Fractions (18 items)	68	75	78
Units and Conversions (18 items)	45	68	73
Scientific Notation (17 items)	47	68	79
Equations (14 items)	46	57	59
Geom. and Trigonometry (14 items)	45	58	61
Total (100 items)	55	69	74

DISCUSSION AND CONCLUSIONS

Although statistically significant differences were found between the mean scores of entering and graduating students, the mean scores of both groups were quite low. Because all students in the graduating group successfully completed the course, it would appear that either these mathematics skills may not be as critical as instructors indicate or criteria for successful course completion are too low. However, the Navy is interested not only in having students pass the BE/E course, but also in a decrease in the amount of time spent in the self-paced course that would mean lower training costs. Hence, if students who possess a high aptitude in mathematics or who become proficient in mathematics during the course complete the course more rapidly, the criticality of the skills becomes more apparent.

Significant differences were found between mean scores for topic areas of entering and graduating students, regardless of whether the topic was considered to be prerequisite to or reviewed or taught during the course. Although significant differences between the mean scores of entering and graduating groups would be anticipated for skills reviewed or taught during course, this is not the case for the skills considered to be prerequisite. When the latter does occur, however, it can usually be attributed to the fact that course prerequisites are also prerequisite, enabling, or subordinate to skills taught during the course, and the skills are used in solving higher order problems.

The fact that entering students achieved a mean group score of 73 percent in Arithmetic Operations and 68 in Fractions, both prerequisites for BE/E school, indicates that they were not very well educated in mathematics in preservice schools. Since BE/E schools do not currently offer remedial training in Arithmetic Operations and in Fractions, some students may begin electronics training with a severe disadvantage.

The statistical differences between the mean scores of graduating students with and without calculators in Arithmetic Operations, Units and Conversions, and Scientific Notation could be expected because of the amount of calculation required for these skills. Although the majority of subjects probably knew the rules of simple arithmetic (addition, subtraction, multiplication, and division), those with calculators were able to avoid the calculation errors that usually result in incorrect problem solutions. For the topic areas of Units and Conversions and Scientific Notation, most problems appear to be related to the number of zeros required and the proper placement of decimal points. Even the most unsophisticated of calculators provide help in these areas, and some possess a scientific notation function. Topic areas in which no significant differences were found between the calculator and noncalculator groups were those that depended on a knowledge of rules for solution and on which calculators had no influence.

RECOMMENDATIONS

Further studies should be conducted to determine (1) if BE/E school mathematics requirements are justified and (2) whether or not they enhance BE/E electronics performance or are needed to enable another skill critical to Class "A" School performance.

These studies are currently being conducted by NAVPERSRANDCEN.

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